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Nonlinear Pulse-reshaping of Sub-picosecond Pulses by Non-degenerate Four-wave Mixing

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Four-wave mixing does according to various models allow for arbitrary pulse-reshaping of the generated idler. Using sub-picosecond pulses, we investigate numerically whether nonlinear effects and dispersion broadening begin to prevent this ability.

Keywords; Nonlinear Optics, Four-wave Mixing, Quantum Information Processing.

VII. Introduction

Quantum information networks depend on the ability to propagate quantum states between linked quantum nodes in a way such that the initial quantum state is preserved [1]. To optimize the information processing an effective process capable of reshaping and frequency converting (FC) quantum states is needed.

One way to obtain quantum-state-preserving FC is using non-degenerate four-wave mixing (FWM) in the specific form called Bragg Scattering (BS) [2,3]. In BS, pumps p and q, enable energy conversion from a signal to an idler wave through a nonlinear interaction between the four fields. Analytical models, predict the ability of arbitrary pulse-reshaping if pump p co-propagates with the signal and pump q co-propagates with the idler [4]. A key parameter of the conversion process is the conversion strength parameter $\bar{\gamma} = 2\gamma_K \left(E_p E_q\right)^{1/2} / |\beta_{1,r} - \beta_{1,s}|$, which contain the Kerr coefficient γ_K, the pump energies $E_{(p,q)}$, and the inverse group speeds of the signal and idler $\beta_{1,(r,s)}$. In this work we investigate whether the reshaping ability is altered when pulses in the sub-picosecond regime are considered.

VIII. Numerical Results

To investigate the pulse-shape, we solve the GNLSE using the split-step Fourier method, setting $\bar{\gamma} = 0.25$, and using a fiber length $L = 10L_{wo} = 10T_0 / |\beta_{1,r} - \beta_{1,s}|$. It is assumed that the natural output modes are Hermite-Gaussian such that the idler-amplitude can be expanded in a basis of these. In Figure 1, the separability S defined as the ratio between the zeroth order expansion coefficient and the sum of all the coefficients is plotted vs. the pulse width T_0 which in this case is the same for all pulses. In another approach, using the selectivity S' defined as the product between S and the lowest-order conversion efficiency, only the width of pump q is varied, which gives different results shown in Figure 2. This result only includes the solution of the full GNLSE in the case of down conversion. The most striking result is the indication that a given pulse-width has a corresponding fiber length yielding maximal selectivty.

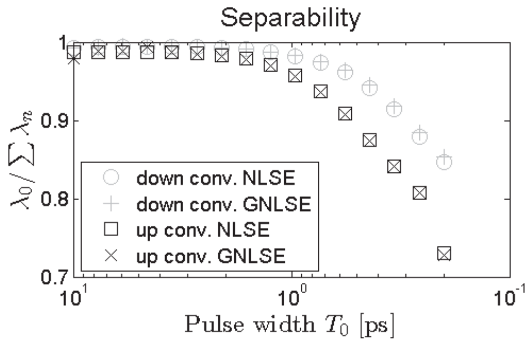

Figure 1. The separability vs. pulse width of the three initial pulse amplitudes.

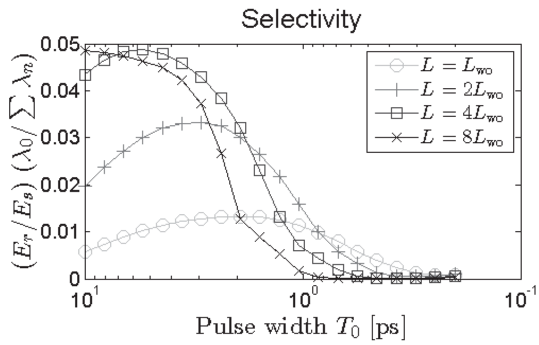

Figure 2. The selectivity vs. pulse width of pump q for four lengths. The initial widths of pump p and the signal is 10 ps.

IX. Conclusion

Pulse-reshaping is prevented in the sub-picosecond regime as a result of dispersion and nonlinear phase modulation. Especially, in the case where the pump-widths differ, reshaping becomes difficult as the fiber length is effectively proportional to the width of the broadest pump.

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